[Third Edition.]

PATENT SPECIFICATION

Application Date: March 16, 1942. No. 3474/42. **556,743**

„ „ Jan. 8, 1943. No. 427/43.

One Complete Specification Left (under Section 16 of the Patents and Designs Acts, 1907 to 1942) : April 13, 1943.

Specification Accepted : Oct. 20, 1943.

PROVISIONAL SPECIFICATION.
No. 3474, A.D. 1942.

Improvements in or relating to the Production of Optical Lenses and other Mouldings in Plastics.

I, ARTHUR WILLIAM KINGSTON, a British Subject, of The Old Will House, Denham, Buckinghamshire, do hereby declare the nature of this invention to be as follows :—

This invention consists of improvements in or relating to the production of optical lenses and other mouldings in plastics and is concerned mainly with the production of lenses, prisms and like optical elements from transparent thermoplastic materials such as those organic polymers (e.g. methyl methacrylate, polystyrene, polyvinyl chloride) which in their finished form are optically clear, uniform, stable and resistant to distortion or change of molecular structure.

In Specification No. 461,398 reference is made to a method of manufacturing optical devices in which a transparent thermoplastic material is given, by a single moulding operation, the shape and highly polished surface necessary, and in patent application No. 801/40 (Serial No. 544,472) a rotary press is described for the moulding of articles say of thermoplastic material wherein a heated die is first brought into light contact with the material in its co-operating mould (also heated) to preheat the material, is then caused to exert a predetermined pressure on the material and is finally withdrawn from contact with the material.

Broadly speaking the present invention relates to the type of operations referred to in these earlier patents. It will be understood that in the moulding operation for a lens, prism or like optical element, the metal dies (generally of special steel) are machined, ground and polished with a very high degree of accuracy so as to have surfaces which will produce in the moulded article corresponding surfaces of that very high degree of optical accuracy associated with glass lenses like those of spectacles, microscopes, telescopes, photographic cameras or cinema projectors. It is contemplated in the present invention that the material inserted into the mould or die shall be a solid workpiece of thermoplastic material of the type above referred to.

During the original solidification or polymerisation of the thermoplastic materials they adopt a molecular structure which is normally uniform and free from internal strains. It has been found that if in the final moulding process the material is subjected to distortion or like strain, the optical properties of the finished element may be interfered with and it is an object of the present invention to overcome or avoid such distortion or strain in the moulding operation.

According to this invention, in the production of lenses, prisms and like optical elements from transparent thermoplastic materials, a solid workpiece is preformed by cutting, grinding and like mechanical operations to a shape closely approximating to its final shape and the preformed workpiece is then subjected to the final moulding in accurate dies to ensure that the lens, prism or other optical element has the shape and surfaces of the optical accuracy demanded.

In a preferred arrangement the workpiece is not only preformed approximately to its final shape by cutting, grinding and like mechanical operations, but the workpiece is also subjected to a polishing operation to remove all roughness, still with the object of bringing the workpiece as closely as possible to its final form.

In the moulding operation it is essential to avoid the formation of air pockets, that is to say, that the preformed workpiece must be of such a shape that during the moulding operation free outlet for air is allowed towards the periphery of the die parts. Thus in the case of the convex surface of a lens where the corresponding matrix is concave, the radius of curvature of the preformed workpiece must not be greater than the radius of curvature of the

[*Price* 1*s.*]

matrix; it should be slightly less than the radius of curvature of the matrix. If, for example, the radius of curvature of the concave matrix were 10 cc., the radius of curvature of the convex surface of the workpiece might be say 9.5—9.8 cc.

Conversely in the case of a concave surface in the lens or other optical element, the radius of curvature of the preformed workpiece should be slightly greater than the convex surface of the die.

This relation between radius of curvature of workpiece and radius of curvature of matrix is achieved in the preforming operation on the workpiece by cutting, grinding or polishing the workpiece accordingly.

In many moulding operations on softened or plastic materials extrusion takes place at or near the periphery of the dies. According to this invention extrusion is avoided as far as possible by two measures:—

(a) the workpiece is made of such a total volume that no part of the volume will be squeezed out around the contiguous edges of the die parts, and

(b) at those parts of the preformed workpiece which are to form the peripheries or edges of the final moulded optical element, the dimensions and shape of the preformed workpiece are brought within very close limits to the final shape.

There is no "flash" in a lens made by this invention.

In the case of a prism of triangular cross-section one of the dies may have a **V**-shaped matrix while the other die is flat, and while the **V**-shaped matrix is of the exact configuration required in the finished prism, the workpiece which is inserted therein has a dihedral angle very slightly less than that of the matrix to prevent the formation of any air pockets during the moulding operation. Similar considerations apply to the formation of prisms having more than three sides.

Dated this 16th day of March, 1942.

BOULT, WADE & TENNANT,
111 & 112, Hatton Garden,
London E.C.1,
Chartered Patent Agents.

PROVISIONAL SPECIFICATION.
No. 427, A.D. 1943.

Improvements in or relating to the Production of Optical Lenses and other Mouldings in Plastics.

I, ARTHUR WILLIAM KINGSTON, a British Subject, of The Old Mill House, Denham, Buckinghamshire, do hereby declare the nature of this invention to be as follows:—

This invention consists of improvements in or relating to the production of optical lenses and other mouldings in plastics and is an improvement on or modification of the invention described in Provisional Specification No. 3474/42. According to the present invention, in the production of lenses, prisms and like optical elements from transparent thermoplastic material a solid workpiece is preformed by cutting, grinding and like mechanical operations to a shape closely approximating to its final shape, this blank is preheated to a temperature suitable for moulding and is then subjected to the final moulding in accurate dies to ensure that the lens, prism or other optical element has the shape and surfaces of the optical accuracy demanded. In the remainder of this specification, the description will be confined to the manufacture of optically accurate lenses.

According to a further feature of this invention, the dies are so mounted in the press that one at least of the dies is under resilient or yielding pressure (e.g. under the pressure of a powerful compressed spring) so that during the cooling and consequent shrinkage of the mould workpiece the movable die may follow up the shrinkage. With this arrangement there is no mechanical stop to the follow up movement of the movable die: the finished workpiece itself is the only stop and the precise dimensions of the finished workpiece are determined by the weight or volume of the preformed blank.

According to a further feature of this invention, the dies are mounted in jackets in the press and the periphery of the dies is embraced by a snug housing (cylindrical in the case of a circular lens); each jacket is provided with conduits for heating fluid like steam and for cooling fluid like water so that during the cooling period the extraction of heat from the workpiece takes place through the dies themselves. The housing or surround is not subjected to water cooling and this arrangement prevents the formation of a solidified and hardened annular zone at the periphery of the cooling workpiece which might inter-

fere with the efficient follow up of the movable die during the final stages of the cooling operation.

In the case of bi-convex or bi-concave lenses the thickness of the lens may vary considerably between its centre and its periphery and the cooling of the die is so arranged that the extraction of heat from the cooling workpiece is substantially uniform over its area or throughout its volume.

The nature of this invention and of subsidiary features thereof will be appreciated from the following description by way of example of the method and apparatus used in the production of lenses from sheets of methyl methacrylate polymer or from polystyrene :—

From a flat sheet of appropriate thickness circular blanks are cut out by a trepanning cutter. Each blank is mounted in a chuck of a lathe and one face is turned to the appropriate curved surface by means of a shaped cutter and the surface thus cut may be ground. The circular blank is then reversed and the other face is similarly cut and ground to the appropriate curved surface. Water is a suitable lubricant for the cutting operation. Stops may be arranged to operate on the carriage of the lathe to ensure that the weight of the preformed blank is correct. The weight and/or dimensions of the preformed blank may also be checked.

Each preformed blank is polished on a rotary buffing machine the objects being to remove the dust-retaining cavities, to obtain close contact with the dies and to facilitate examination of the surface for dust or other contamination or for surface markings.

The moulding press in its main essentials is of standard form. The jacket for the lower die is mounted in the lower part of the press (in this example the movable part). The jacket for the upper die is mounted on the bottom of a plunger which is accurately guided in a cylinder (compression pot) on the upper part of the press and between plunger and cylinder is a powerful compression spring tending to force the upper die downwards. Each die-holding jacket is provided with fluid-circulating conduits so disposed in the jacket that the application of heat to the die or the extraction of heat from the die takes place through the back of the die; while the operative faces of the die are machined, ground and polished with a very high degree of accuracy. The back face of each die is also accurately ground to give perfect contact with the correspondingly ground surface of the jacket.

Electric ovens are used for preheating the blank and these ovens are preferably arranged within easy reach of the press operator. For example, for lenses of a maximum diameter 1 to 2 inches ovens may be mounted on the framework of the press and electrically heated, the temperature being controlled by rheostats. A clean lens blank is conveniently gripped in suitably shaped tongs contacting only with the periphery of the blank and that part of the tongs holding the blank can be introduced into the oven. In the case of methyl methacrylate blanks the preheating temperature in the case of some lenses may be as high as 130°—140° C. although this depends to some extent on the size of the lens. In the case of polystyrene blanks the preheating temperature may be as high as 100° C.—110° C. Means are employed to ensure that the air in the ovens is clean.

The fluid conduits in the die jackets are arranged to be put in communication with either a steam manifold or a cooling water manifold.

The operation of moulding is as follows :—Both the dies and the blanks are made optically clean. The blank after preheating is deposited in the lower die which is embraced by the surround or housing and by the normal operation of the press contact is established between the blank and both dies which at this stage are heated to the moulding temperature. The pressure in the case of methyl methacrylate blanks is about 2 tons per square inch and in the case of polystyrene blanks is about 1 ton per square inch. The times of moulding at the high temperature above referred to vary somewhat with the dimensions of the lens but may be 2 to 3 minutes. Then the steam is turned off and the die-holding jackets are cooled by the circulation of water through the conduits. It is at this stage the upper die makes the follow up. In other words the pressure is maintained during cooling and the action of the compressed spring on the upper die forces the surface of the dies to remain in perfect contact with the moulded surfaces of the lens until solidification is complete. With lenses of 1 to 2 inches diameter the time of cooling under pressure may be 3 to 3½ minutes.

When the press is opened, the bottom die is lifted out of the surround by mechanically raising it. The moulded lens has no flash. The edges of the periphery may be slightly rough and may be readily smoothed.

The following points should be noted in connection with the improved process described : the process enables optically-accurate lenses and other optical goods to be manufactured from plastics in a closed mould and without the use of a positive stop, in such a way that the finished

articles are free from harmful internal strain, are of desired thickness, and will retain their shape and optical characteristics unimpaired for an indefinite time despite the usual temperature and atmospheric changes.

One result of preforming the blank very nearly to the final curvature is that very little material remains to be moved by the dies in the moulding operation. The preform in general is sufficiently close to the final curvature so that each face of the lens only requires reduction by the moulding operation to a slight extent. This reduction is accomplished, the preheated die being at correct temperature by a slight radial flow outwards from the centre, without the formation of harmful internal stress patterns whereas, if the lens curvatures were to be formed entirely by die pressure, from a flat blank of uniform thickness, in a closed mould, the product would generally be found to contain internal stress patterns of a harmful character. It is of course to be noted that the formation of the curved preform by a cutting operation does not tend to stress the material as does a moulding operation of sufficient magnitude to form the curved surface from the flat, where the material is not free to flow out of the mould. Another advantage of the use of the curved preform is that thereby the formation of air pockets in the mould is prevented.

Further, the absence of a fixed stop limiting the movement of the die is important, because of the observed fact that the plastic material shrinks somewhat during cooling, and with the process herein described close contact of the dies with the material is maintained until the product has finally set, which is impossible when a fixed stop is used. In this connection the method of cooling the blank uniformly throughout its surfaces, by extracting heat through the backs of the dies, is important because if cooling took place through the surround the peripheral portion of the lens would tend to harden first, thus preventing the follow-up pressure from maintaining close contact with the entire curved surfaces of the lens.

The required final thickness of the lens may be predetermined quite exactly, by making the preform of a calculated weight and volume together with knowledge, readily gained by experience with different materials, of the reduction in thickness which will result from the pressure under heat and the subsequent shrinkage during cooling.

Dated this 8th day of January, 1943.

BOULT, WADE & TENNANT.
111 & 112, Hatton Garden,
London, E.C.1,
Chartered Patent Agents.

COMPLETE SPECIFICATION.

Improvements in or relating to the Production of Optical Lenses and other Mouldings in Plastics.

I, ARTHUR WILLIAM KINGSTON, a British Subject, of The Old Mill House, Denham, Buckinghamshire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

This invention consists of improvements in or relating to the production of optical lenses and other mouldings in plastics and is concerned mainly with the production of lenses, prisms and like optical elements from transparent thermoplastic materials such as those organic polymers (e.g. methyl methacrylate, polystyrene, polyvinyl chloride) which in their finished form are optically clear, uniform, stable and resistant to distortion or change of molecular structure.

In Patent Specification No. 416,398 reference is made to a method of manufacturing optical devices in which a transparent thermoplastic material is given, by a single moulding operation, the shape and highly polished surfaces necessary, and in Patent Specification No. 544,472 a rotary press is described for the moulding of articles say of thermoplastic material wherein a heated die is first brought into light contact with the material in its co-operating mould (also heated) to preheat the material, is then caused to exert a predetermined pressure on the material and is finally withdrawn from contact with the material.

Broadly speaking the present invention relates to the type of operations referred to in these earlier patent specifications. It will be understood that on the moulding operation for a lens, prism or like optical element, the metal dies (generally of special steel) are machined, ground and polished with a very high degree of accuracy so as to have surfaces which will produce in the moulded article corresponding surfaces of that very high degree of optical accuracy associated with glass

lenses like those of spectacles, microscopes, telescopes, photographic cameras or cinema projectors. It is contemplated in the present invention that the material inserted into the mould or die shall be a solid workpiece of thermoplastic material of the type above referred to.

During the original solidification or polymerisation of the thermoplastic materials they adopt a molecular structure which is normally uniform and free from internal strains. It has been found that if in the moulding process the material is subjected to distortion or like strain, the optical properties of the finished element may be interfered with and it is an object of the present invention to overcome or avoid such distortion or strain in the moulding operation.

According to this invention, in the production of lenses, prisms and like optical elements from transparent thermoplastic materials, a solid workpiece is preformed by cutting, grinding or like mechanical operations to a shape closely approximating to its final shape and the preformed workpiece is then subjected to the final moulding in accurate dies to ensure that the lens, prism or other optical element has the shape and surfaces of the optical accuracy demanded.

In a preferred arrangement the workpiece is not only preformed approximately to its final shape by cutting, grinding or like mechanical operations, but the workpiece is also subjected to a polishing operation to remove all roughness, still with the object of bringing the workpiece as closely as possible to its final form.

In the moulding operation it is essential to avoid the formation of air pockets, that is to say, the preformed workpiece must be of such shape that during the moulding operation free outlet for air is allowed towards the periphery of the die parts. Thus in the case of the convex surface of a lens where the corresponding matrix is concave, the radius of curvature of the preformed workpiece must not be greater than the radius of curvature of the matrix; it should be slightly less than the radius of curvature of the matrix. If, for example, the radius of curvature of the concave matrix were 10 cm., the radius of curvature of the convex surface of the workpiece might be say 9.5—9.8 cm.

Conversely in the case of a concave surface in the lens or other optical element, the radius of curvature of the preformed workpiece should be slightly greater than that of the convex surface of the die.

This relation between radius of curvature of workpiece and radius of curvature of matrix is achieved in the preforming operation on the workpiece by cutting, grinding or polishing the workpiece accordingly.

In many moulding operations on softened or plastic materials extrusion takes place at or near the periphery of the dies. According to this invention extrusion is avoided as far as possible by two measures:—

(a) the workpiece is made of such a total volume that no part of the volume will be squeezed out around the contiguous edges of the die parts, and

(b) at those parts of the preformed workpiece which are to form the peripheries or edges of the final moulded optical element, the dimensions and shape of the preformed workpiece are brought within very close limits to the final shape.

There is no "flash" in a lens made by this invention.

In the case of a prism of triangular cross-section one of the dies may have a **V**-shaped matrix while the other die is flat, and while the **V**-shaped matrix is of the exact configuration required in the finished prism, the workpiece which is inserted therein has a dihedral angle very slightly less than that of the matrix to prevent the formation of any air pockets during the moulding operation. Similar considerations apply to the formation of prisms having more than three sides.

According to the present invention, in the production of lenses, prisms and like optical elements from transparent thermoplastic material a solid workpiece is preformed by cutting, grinding or like mechanical operations to a shape closely approximating to its final shape, this blank is preheated to a temperature suitable for moulding and is then subjected to the final moulding in accurate dies to ensure that the lens, prism or other optical element has the shape and surfaces of the optical accuracy demanded. In the remainder of this specification, the description will be confined to the manufacture of optically accurate lenses.

According to a further feature of this invention, the dies are so mounted in the press that one at least of the dies is under resilient or yielding pressure (e.g. under the pressure of a powerful compressed spring) so that during the cooling and consequent shrinkage of the moulded workpiece the movable die may follow up the shrinkage. With this arrangement there is no mechanical stop to the follow up movement of the movable die: the finished workpiece itself is the only stop and the precise dimensions of the finished workpiece are determined by the weight or volume of the preformed blank.

According to a further feature of this invention, the dies are mounted in jackets

in the press and the periphery of the dies is embraced by a snug housing (cylindrical in the case of a circular lens); each jacket is provided with conduits for heating fluid such as steam and for cooling fluid such as water so that during the cooling period the extraction of heat from the workpiece takes place through the dies themselves. The housing or surround is not subjected to water cooling and this arrangement prevents the formation of a solidified and hardened annular zone at the periphery of the cooling workpiece which might interfere with the efficient follow up of the movable die during the final stage of the cooling operation.

In the case of bi-convex and bi-concave lenses the thickness of the lens may vary considerably between its centre and its periphery and the cooling of the die is so arranged that the extraction of heat from the cooling workpiece is substantially uniform over its area or throughout its volume.

The nature of this invention and of subsidiary features thereof will be appreciated from the following description by way of example of the method and apparatus used in the production of lenses from sheets of methyl methacrylate polymer or from polystyrene, reference being made to the accompanying drawings in which :—

Figure 1 is a perspective view of the moulding apparatus,

Figure 2 is a perspective view partly in section, showing the lens-holding tongs and electric heating device,

Figure 3 is a detail view in vertical section illustrating the operation of ejecting the lens from the press,

Figure 4 is a vertical sectional view of part of the press including the top and bottom dies and their associated parts, the lens being under pressure.

From a flat sheet of appropriate thickness circular blanks are cut out by a revolving trepanning cutter. Each blank is mounted in a chuck of a lathe and one face is turned to the appropriate curved surface by means of a shaped cutter and the surface thus cut away be ground. The circular blank is then reversed and the other face is similarly cut and ground to the appropriate curved surface. Water is a suitable lubricant for the cutting operation. Stops may be arranged to operate on the carriage of the lathe to ensure that the weight of the preformed blank is correct. The weight and/or dimensions of the preformed blank may also be checked.

Each preformed blank is polished on a rotary buffing machine, the objects being to remove the dust-retaining cavities, to obtain close contact with the dies and to facilitate examination of the surface for dust or other contamination or for surface markings.

The moulding press in its main essentials is of standard form. The cylindrical housing or surround 10 and the jacket 11 for the lower die 12 are mounted in the lower part of the press (in this example the movable part 13). The jacket 14 for the upper die 15 is mounted on the bottom of a plunger 16 which is accurately guided in a cylinder 17 (compression pot) on the upper part of the press and between plunger and cylinder is a powerful compression spring 18 tending to force the upper die 15 downwards. The lower die-holding jacket 11 is provided with fluid-circulating conduits 19 for cold water and 20 for steam. The upper die-holding jacket 14 is provided with fluid-circulating conduits 21 for cold water and 22 for steam. The passages in the jackets themselves are so disposed that the application of heat to the die or the extraction of heat from the die takes place through the back of the die. The operative faces of the dies are machined, ground and polished with a very high degree of accuracy. The back face of each die is also accurately ground to give perfect contact with the correspondingly ground surface of the jacket.

Electric ovens 23 are used for preheating the lens-blanks 24 and these ovens are preferably arranged within easy reach of the press operator. For example, for lenses of a maximum diameter 1 to 2 inches, ovens 23 may be mounted on the framework 25 of the press and electrically heated, the temperature being controlled by rheostats 26. A clean lens-blank is conveniently gripped in suitably shaped tongs 27 contacting only with the periphery of the blank and that part of the tongs holding the blank can be introduced into the oven. In the case of a methyl methacrylate blank the preheating temperature in the case of some lenses may be as high as 130° C.—140° C. although this depends to some extent on the size of the lens. In the case of polystyrene blanks the preheating temperature may be as high as 100°—110° C. Means are employed to ensure that the air in the ovens is clean.

The fluid conduits in the die jackets are arranged to be put in communication with either a steam manifold 28 or a cooling water manifold 29.

Referring to Figure 3, the lower die 12 is coupled by a rod 30 to a yoke 31 vertically movable in guides 32 in the movable part 13 of the press. The yoke 31 engages the pivoted hand-lever 33 so that when the moulding operation is completed and the movable part 13 is lowered (by the standard hydraulic gear) the hand-lever 33 may be raised to eject and to press up the

lower die 12 within the housing 10 and thus eject the finished lens.

The operation of moulding is as follows:—Both the dies 12 and 15 and the blanks 24 are made optically clean. The blank 24 after preheating in the oven 23 is deposited in the lower die 12 which is embraced by the surround or housing 10 and by the normal operation of the press 34 contact is established between the blank 24 and both dies 12 and 15, the jackets of which, 11 and 16, at this stage are heated through the steam conduits 20 and 22 to the moulding temperature. The pressure in the case of methyl methacrylate blanks is about 2 tons per square inch and in the case of polystyrene blanks is about 1 ton per square inch. The times of moulding at the high temperature above referred to vary somewhat with the dimensions of the lens but may be 2 to 3 minutes. Then the steam is turned off and the die-holding jackets 11 and 14 are cooled by the circulation of water through the conduits 19 and 21. It is at this stage that the upper die 15 makes the follow up. In other words the pressure is maintained during cooling and the action of the compressed spring 18 on the upper die 15 forces the surface of the dies to remain in perfect contact with the moulded surfaces of the lens 24 until solidification is complete. With lenses of 1 to 2 inches diameter the time cooling under pressure may be 3 to 3½ minutes.

When the press is opened, the bottom die 12 is lifted out of the surround 10 by mechanically raising it. The edges of the periphery may be slightly rough and may be readily smoothed.

The following points should be noted in connection with the improved process described: the process enables optically-accurate lenses and other optical goods to be manufactured from plastics in a closed mould and without the use of a positive stop, in such a way that the finished articles are free from harmful internal strain, are of desired thickness, and will retain their shape and optical characteristics unimpaired for an indefinite time despite the usual temperature and atmospheric changes.

One result of preforming the blank very nearly to the final curvature is that very little material remains to be moved by the dies in the moulding operation. The preform in general is sufficiently close to the final curvature so that each face of the lens only requires reduction by the moulding operation to a slight extent. This reduction is accomplished, the preheated die being at correct temperature, by a slight radial flow outwards from the centre, without the formation of harmful internal stress patterns whereas, if the lens curvatures were to be formed entirely by die pressure, from a flat blank of uniform thickness, in a closed mould, the product would generally be found to contain internal stress patterns of a harmful character. It is of course to be noted that the formation of the curved preform by a cutting operation does not tend to stress the material as does a moulding operation of sufficient magnitude to form the curved surface from the flat, where the material is not free to flow out of the mould. Another advantage of the use of the curved preform is that thereby the formation of air pockets in the mould is prevented.

Further, the absence of a fixed stop limiting the movement of the die is important, because of the observed fact that the plastic material shrinks somewhat during cooling, and with the process herein described close contact of the dies with the material is maintained until the product has finally set, which is impossible when a fixed stop is used. In this connection the method of cooling the blank uniformly throughout its surfaces by extracting heat through the backs of the dies, is important because if cooling took place through the surround the peripheral portion of the lens would tend to harden first, thus preventing the follow-up pressure from maintaining close contact with the entire curved surfaces of the lens.

The required final thickness of the lens may be predetermined quite exactly, by making the preform of a calculated weight and volume together with knowledge, readily gained by experience with different materials, of the reduction in thickness which will result from the pressure under heat and the subsequent shrinkage during cooling.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. The method for the production of lenses, prisms and like optical elements from transparent thermoplastic materials such as methyl methacrylate polymer or polystyrene in which a solid workpiece is preformed by cutting, grinding or like mechanical operations to a shape closely approximating to its final shape and the preformed workpiece is then subjected to moulding in accurate dies to ensure that the element has the shape and surfaces of the optical accuracy demanded.

2. A method as claimed in claim 1 in which the workpiece is not only preformed approximately to its final shape by cutting, grinding or like mechanical operations but is also subjected to a polishing opera-

tion to remove all roughness prior to moulding.

3. A method as claimed in claim 1 or in claim 2 in which the moulding dies and the preformed workpiece are of such relative shapes that during the moulding operation free outlet for air is allowed towards the periphery of the die parts.

4. A method as claimed in any of the preceding claims for the production of a lens in which the radius of curvature of the preformed workpiece if convex is slightly less (and if concave is slightly greater) than that of the corresponding die surface.

5. A method as claimed in any of the preceding claims in which the preformed workpiece is preheated to a temperature suitable for moulding and is then subjected to the moulding by heated dies.

6. A method as claimed in claim 5 in which the preformed workpiece is held by tongs adapted to grip only the periphery thereof and is heated in an oven.

7. A method as claimed in any of the preceding claims in which the dies are so mounted in the moulding press that one at least of the dies is under resilient or yielding pressure (e.g. under the pressure of a powerful compressed spring) so that during the cooling and consequent shrinkage of the moulded workpiece the movable die may follow up the shrinkage.

8. A method as claimed in any of the preceding claims in which the dies are mounted in jackets in the press and each jacket is provided with conduits for heating fluid such as steam and for cooling fluid such as water so that during the cooling period the extraction of heat from the workpiece takes place through the dies themselves.

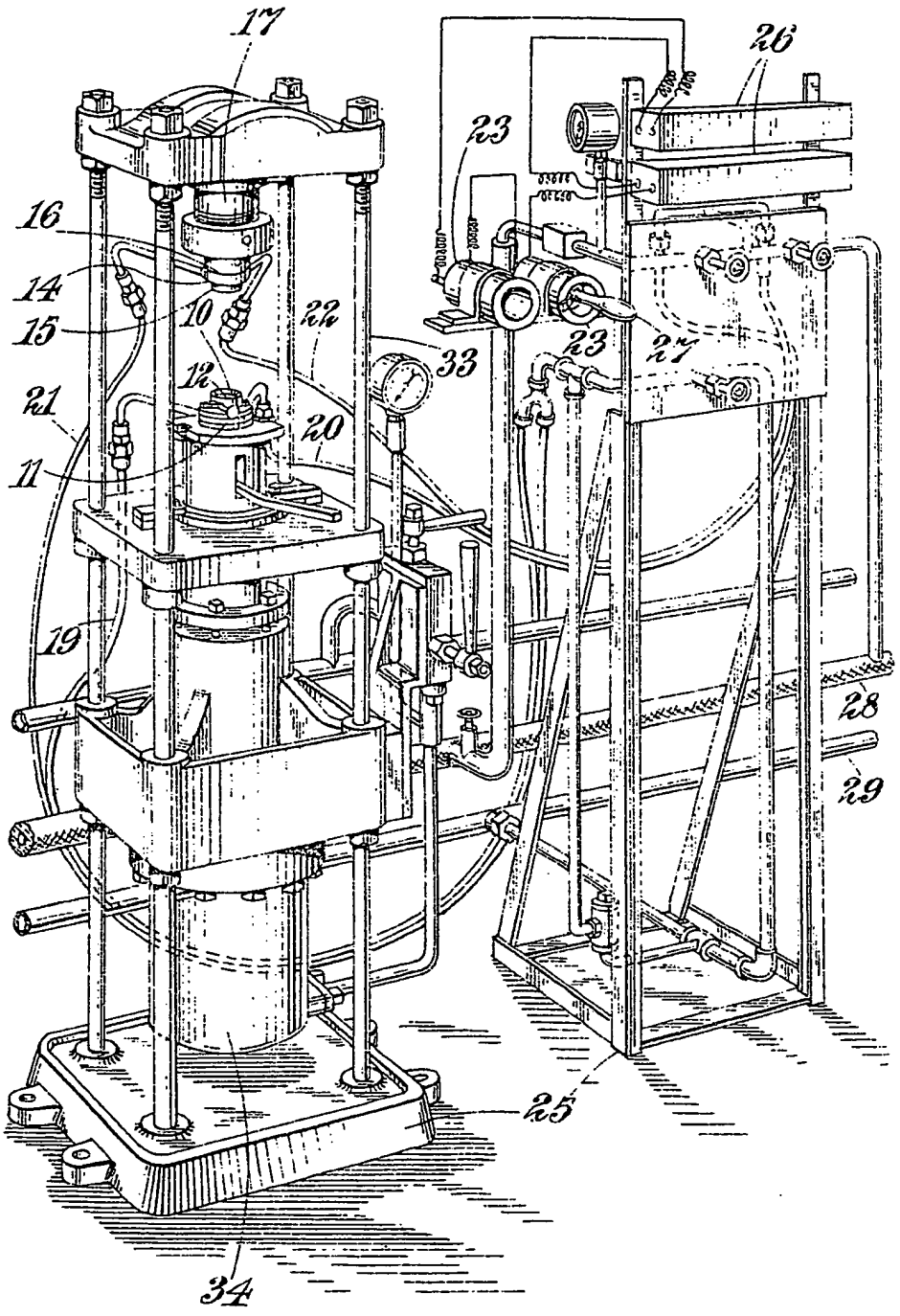
9. A method as claimed in claim 8, in which the rate of cooling of each die over the different zones of its contact surface is so arranged that the extraction of heat from the cooling workpiece is substantially uniform throughout its volume.

10. The complete method for the production of lenses from transparent thermoplastic materials such as methyl methacrylate polymer or polystyrene substantially as described with reference to the accompanying drawings.

Dated this 13th day of April, 1943.
BOULT, WADE & TENNANT,
111 & 112, Hatton Garden,
London, E.C.1,
Chartered Patent Agents.

Abingdon: Printed for His Majesty's Stationery Office, by Burgess & Son.
[Wt. 8229A.—1/1947.]

Fig. 1.



[This Drawing is a reproduction of the Original on a reduced scale.]

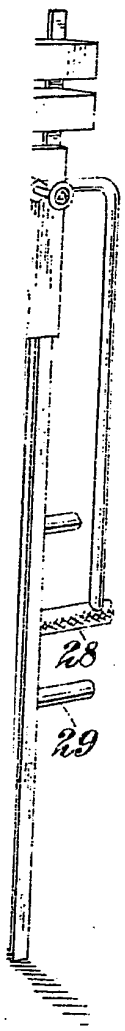


Fig. 2.

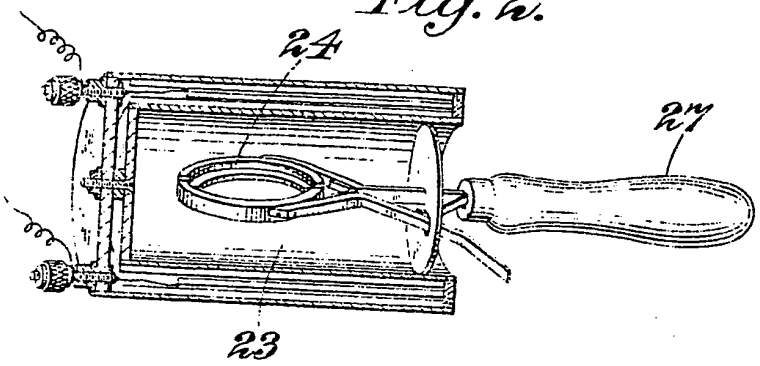
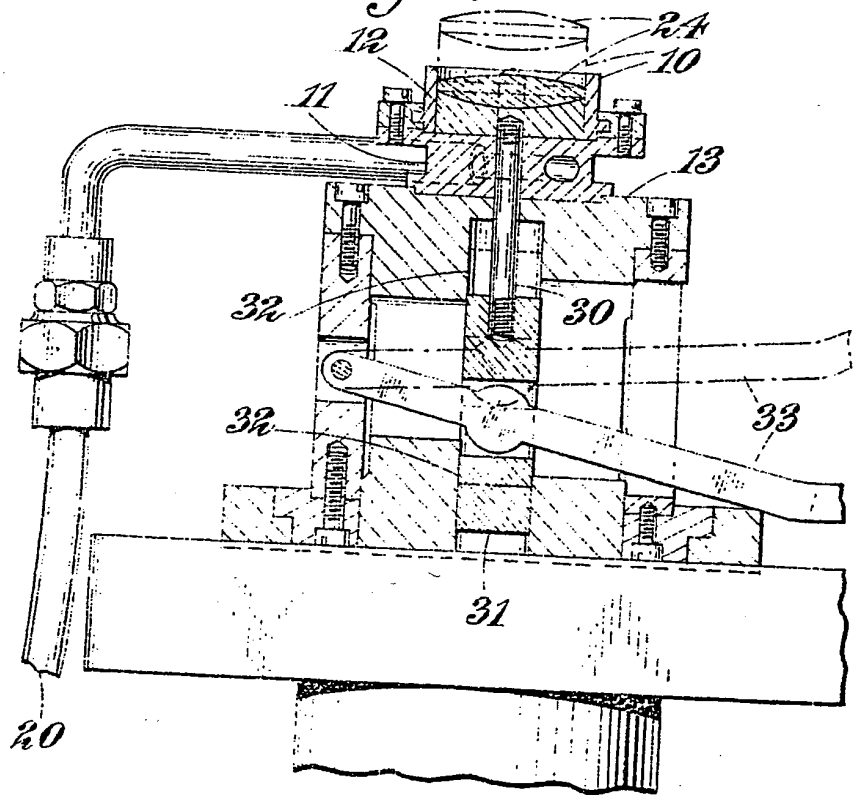


Fig. 3.



556,743 COMPLETE SPECIFICATION

3 SHEETS

3rd Edition

SHEET 1

SHEET 2

[This Drawing is a reproduction of the Original on a reduced scale]

Fig. 1.

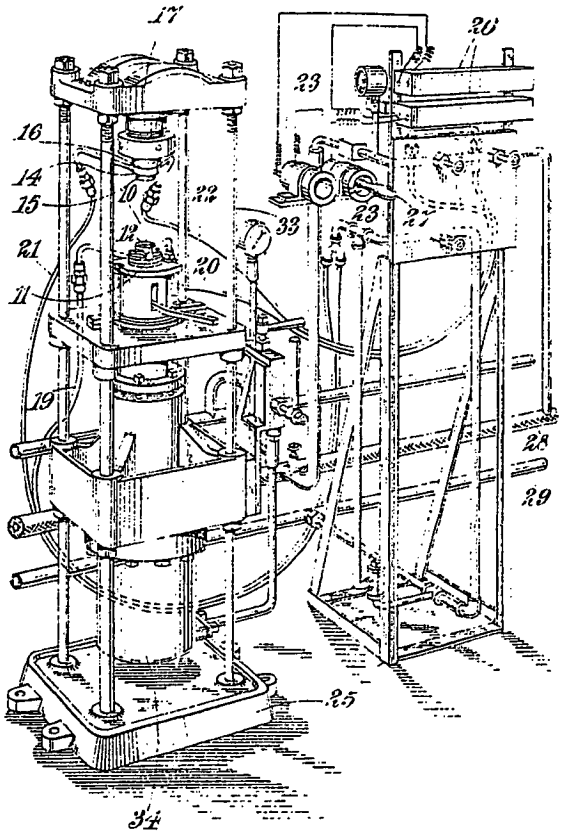


Fig. 2.

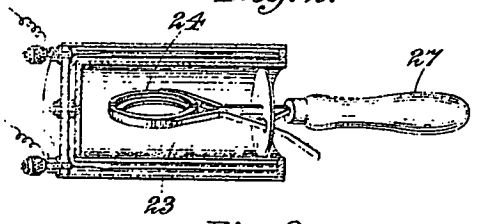


Fig. 3.

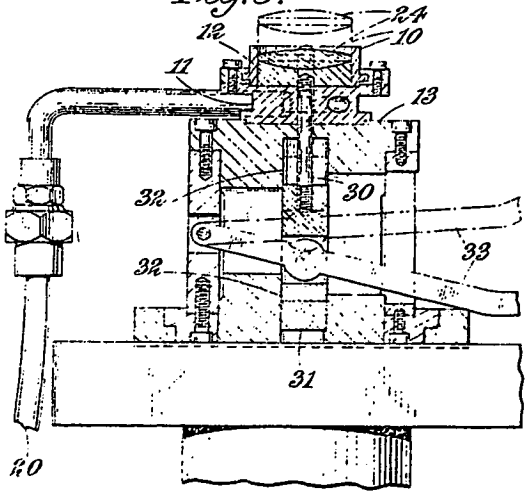
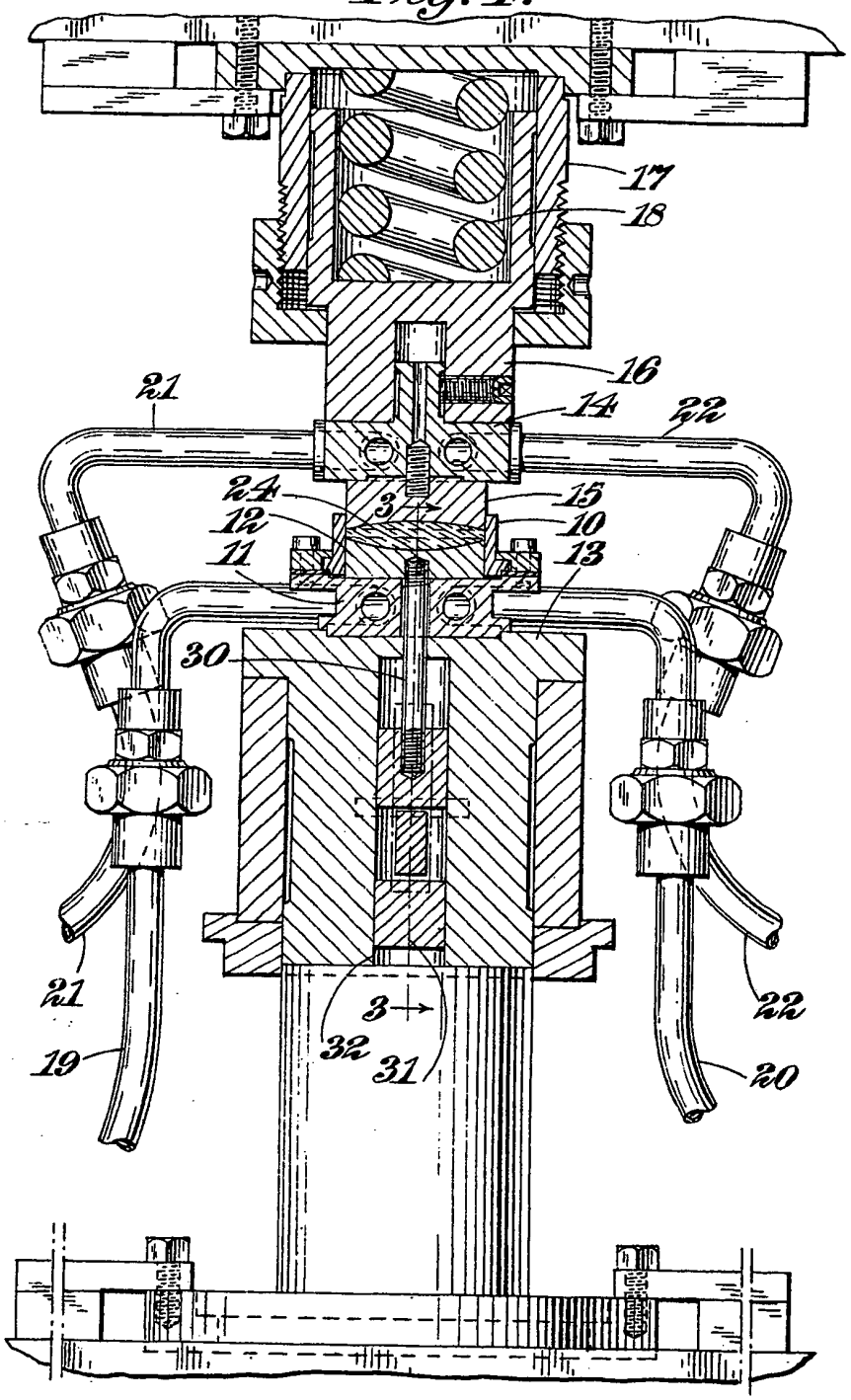


Fig. 4.



[This Drawing is a reproduction of the Original on a reduced scale.]

H.M.S.O. (Ty.P.)